

Development of a sorption-based JT cooler for the METIS instrument on E-ELT

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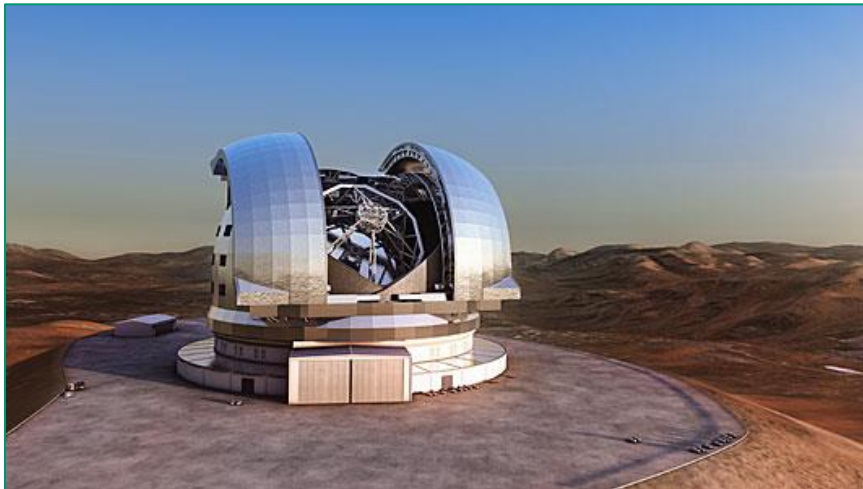
(1)



AIRBUS
DEFENCE & SPACE

(2)

European Southern Observatory's (ESO) next generation, ground-based large telescope for optical/near-infrared range.

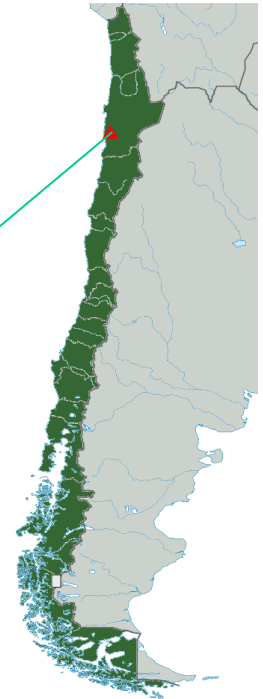


Artist's impression of the E-ELT, <https://www.eso.org/public/images/eso1225a/>



E-ELT vs VLT and Colosseum, <http://www.eso.org/public/images/e-elt-and-vlt-vscolosseum/>

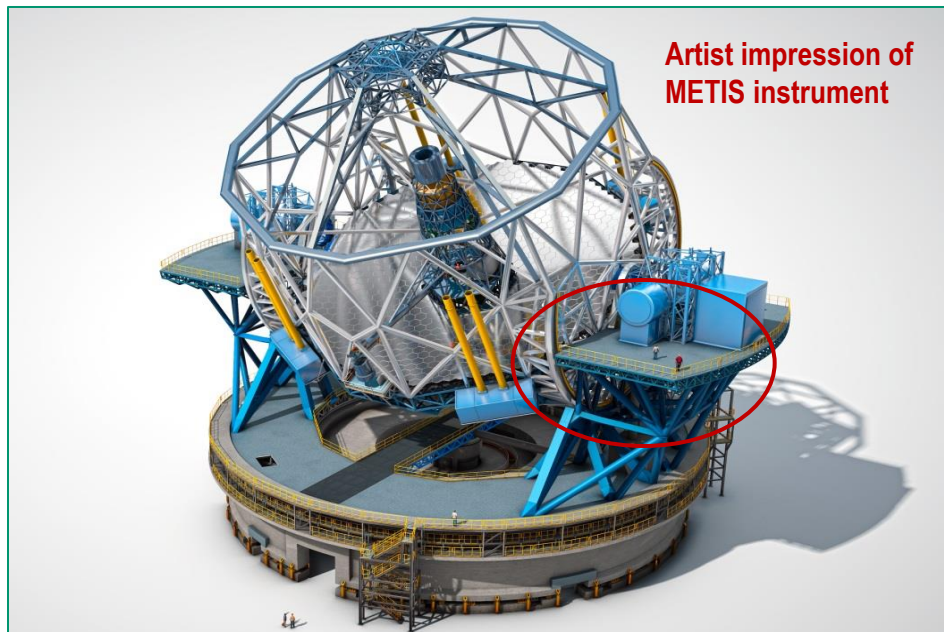
Site: Cerro Armazones, Chile
Altitude: 3060 m



- Main mirror diameter: **39 m**;
- **798** hexagonal segments, each **1.45 m** wide but only **50 mm** thick;
- Gathering **15 times** more light than the current largest optical telescopes.

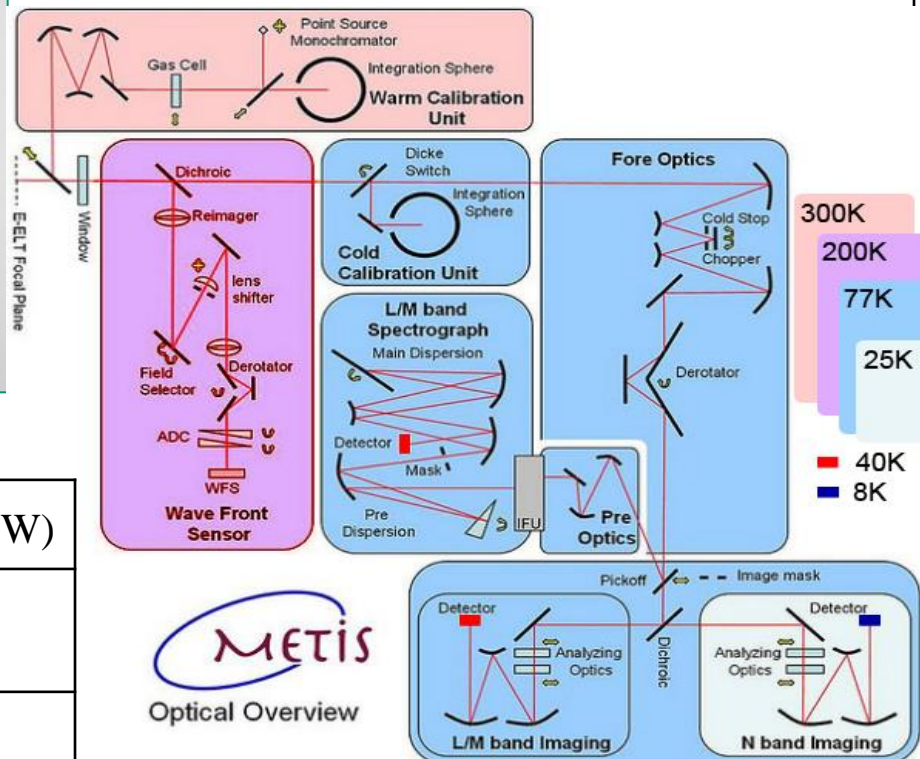
Background

METIS instrument in E-ELT



METIS: Mid-infrared E-ELT Imager and Spectrograph

Objective: Offer imaging and spectroscopy over the wavelength range of 3-14 μm

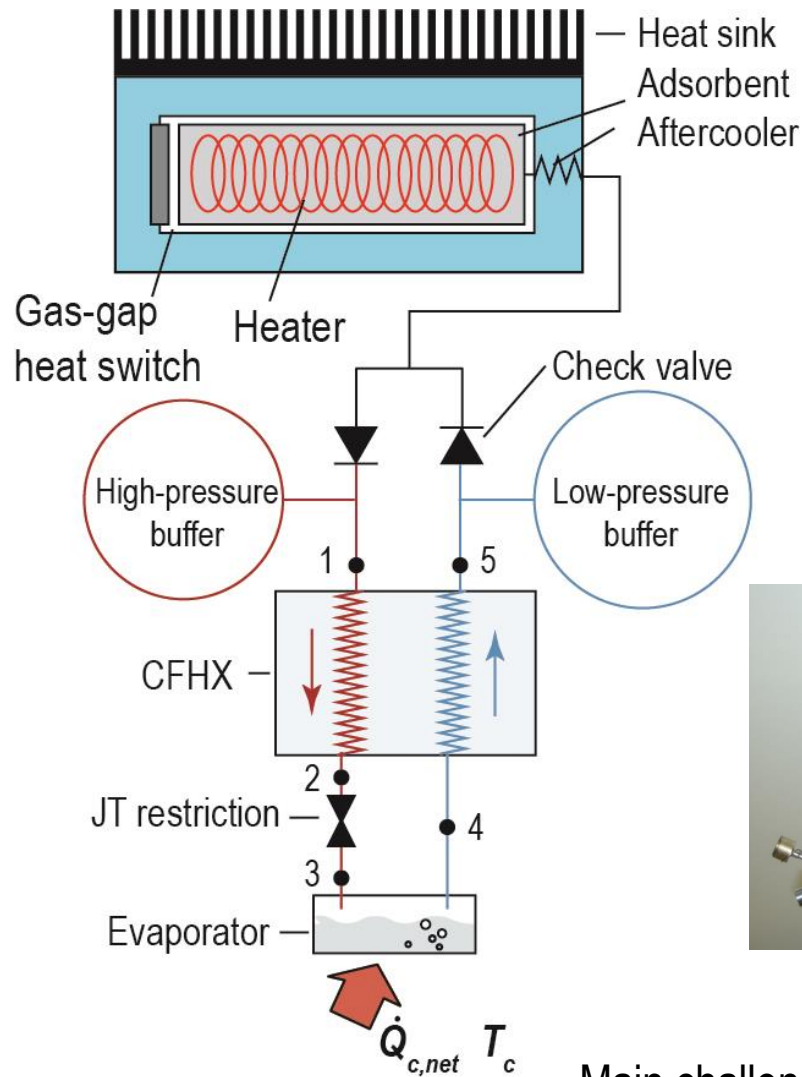


METIS units	Working Temp. (K)	Heat load (W)
LM-Band Detectors	40	1.4
N-Band Imager	25	1.1
N-Band Detectors	8	0.4



Vibration Free !

Sorption cooler heritage at University of Twente (mostly under ESA contracts)



4.5 K helium cooler
(CEC 2007)



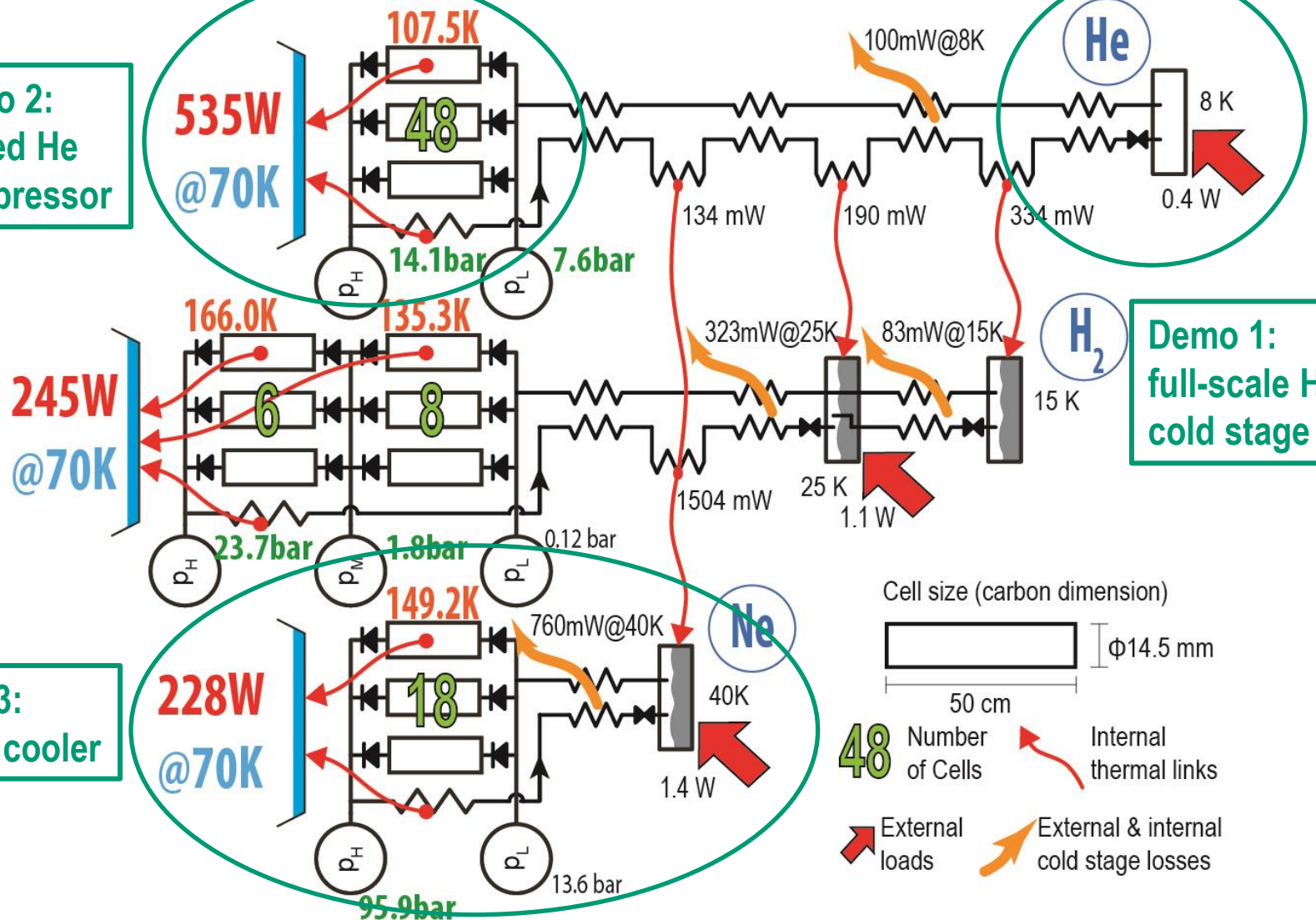
14.5 K hydrogen cooler (CEC 2013)



Main challenge: how to get from ESA milliWatt level to ESO Watt level

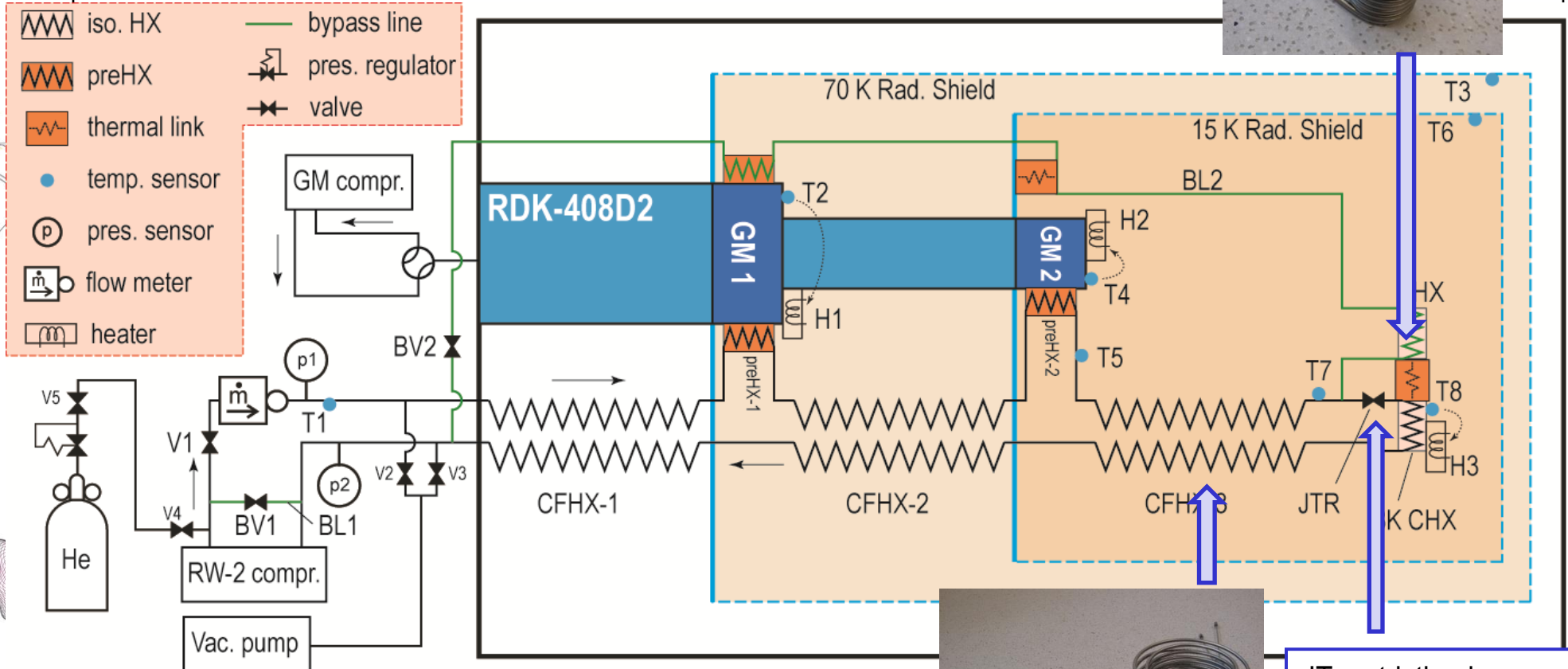
Baseline design and demonstrators

Demo 2:
scaled He
compressor



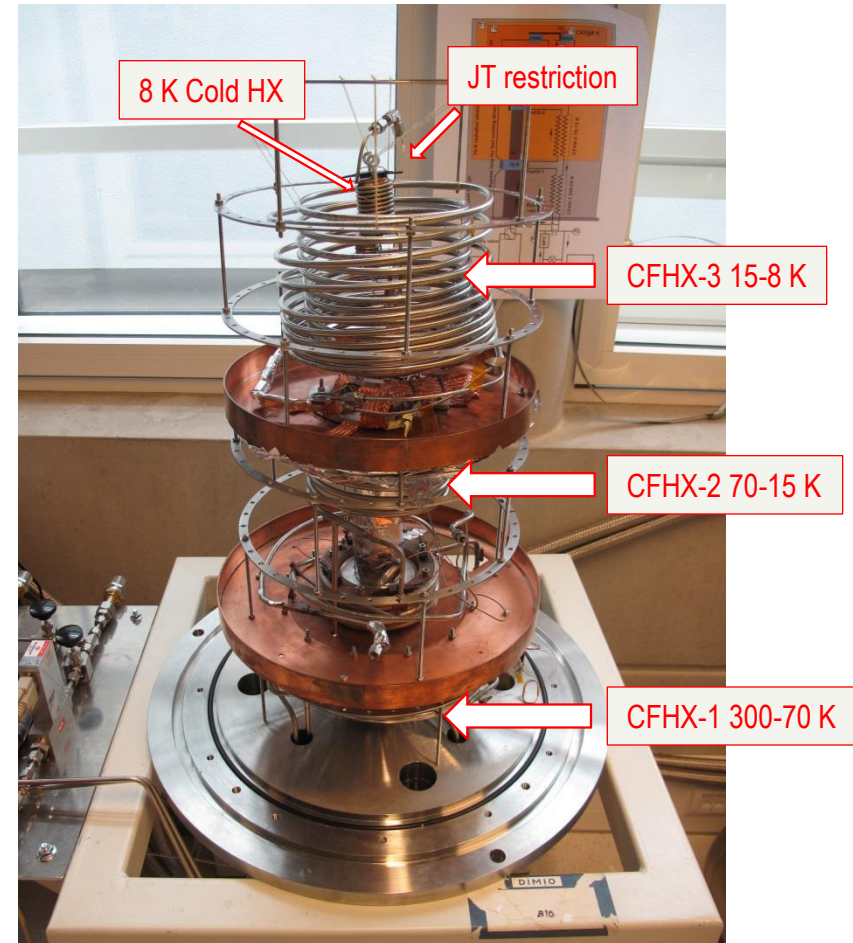
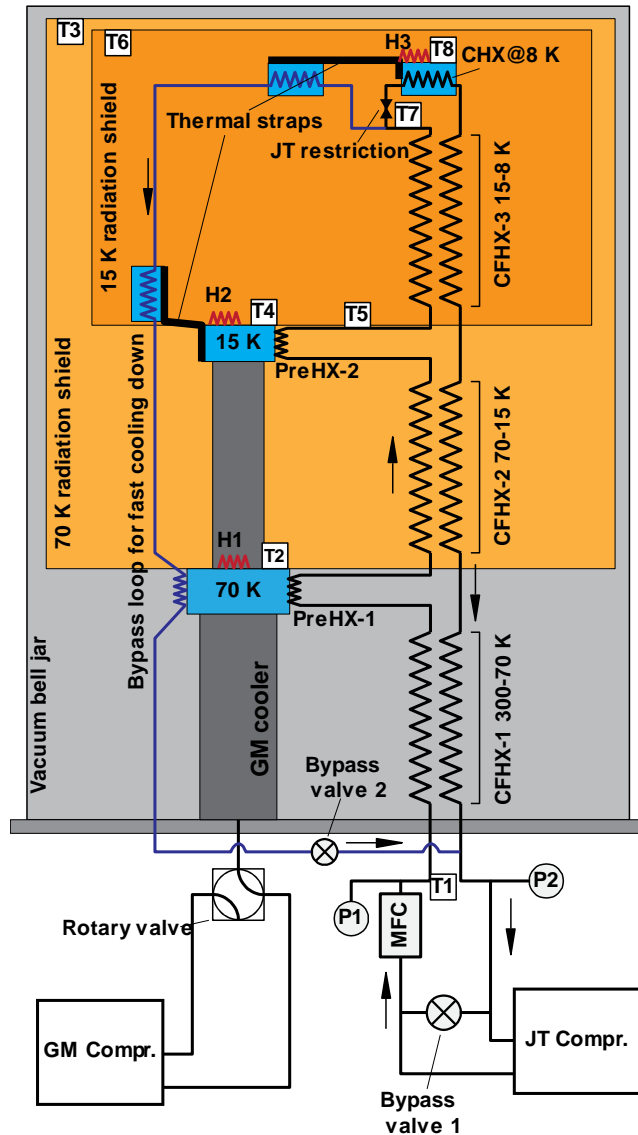
Demo 1: full-scale He cold stage

8 K heat exchanger: spiraled 1/8"x 0.028" tube of 1.3 m length (0.8 m required)







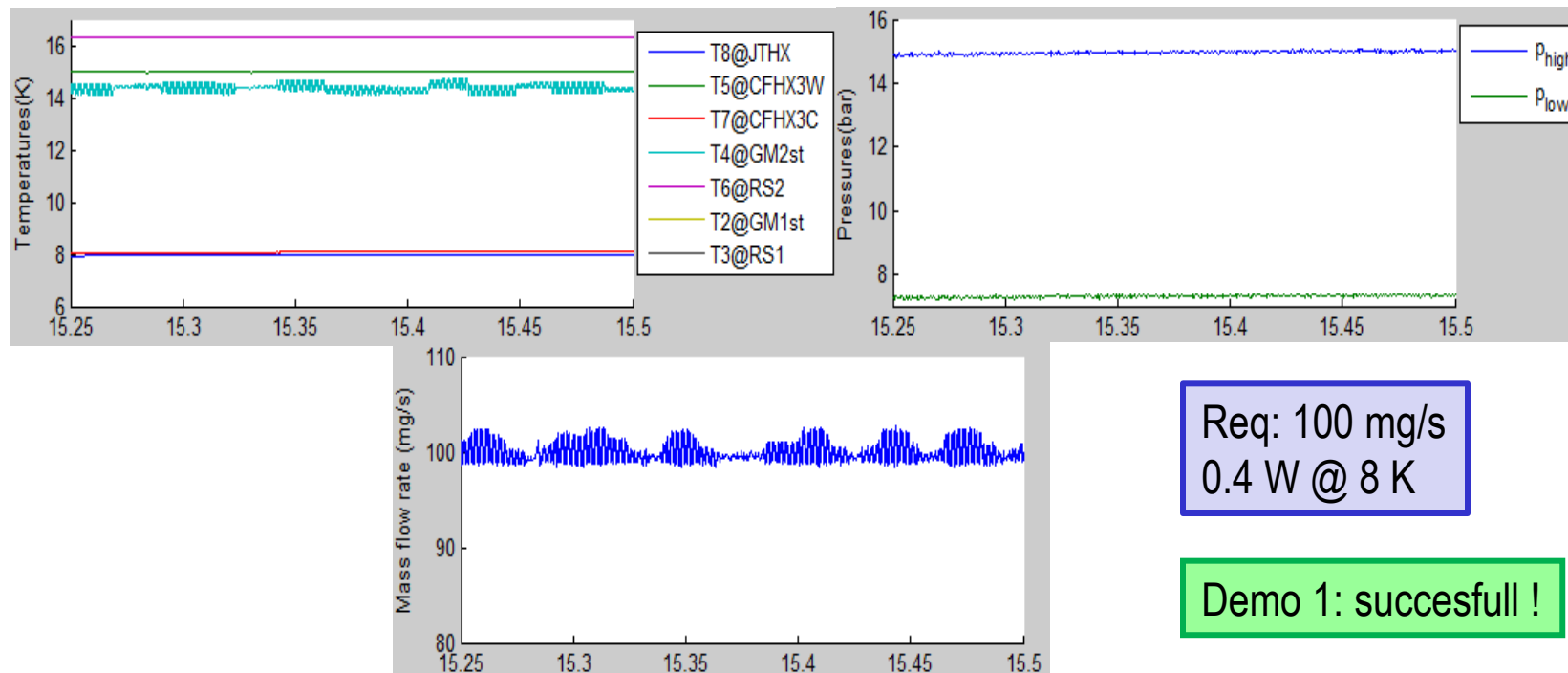
JT restriction is capillary tube diameter 0.2 mm, length 15 cm

Demo 1: full-scale He cold stage



Demo 1: full-scale He cold stage experimental results

	Average	Max.  in 30 minutes  Min.	in 30 minutes
T _c (T8)	7.977	7.996	7.933  Temp. stability < 0.07 K
Q _c (H3)	0.422	0.424	0.417  Q _c stability < 10 mW
P _{high}	14.960	15.076	14.798
P _{low}	7.307	7.392	7.202
mf	99.950	102.728	98.436



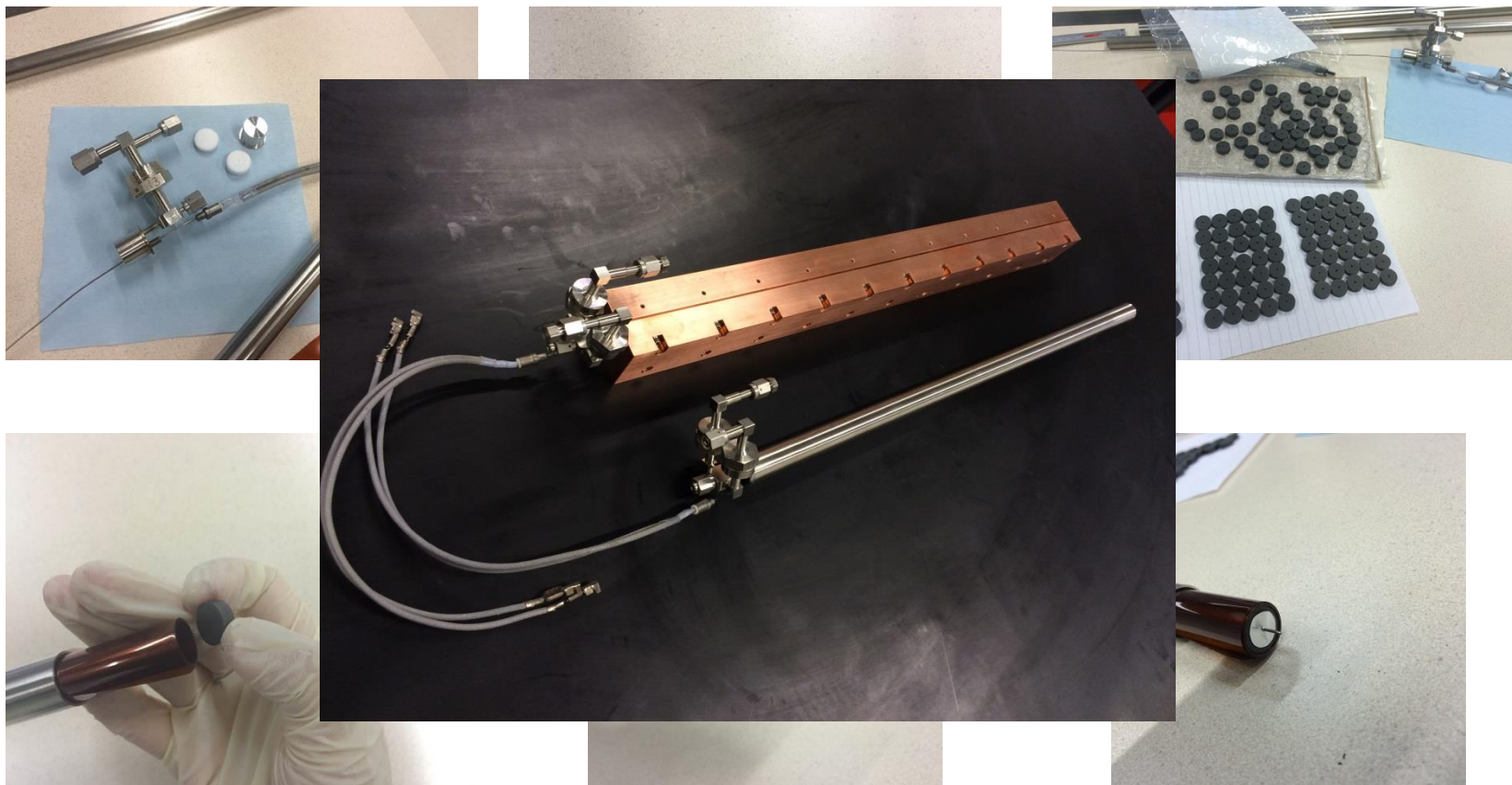
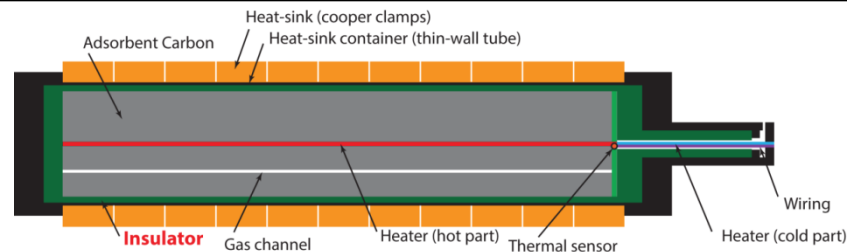
Req: 100 mg/s
0.4 W @ 8 K

Demo 1: succesfull !

Demo 2: scaled He sorption compressor

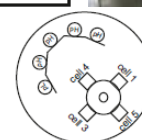
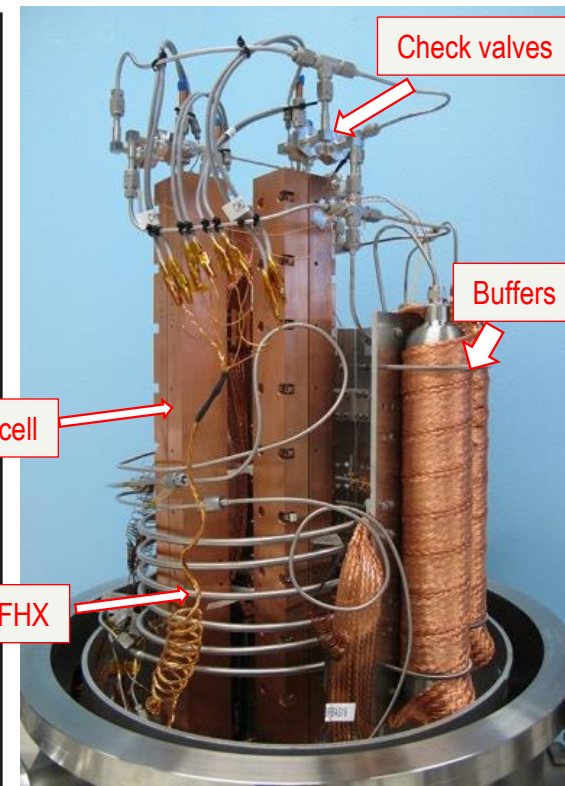
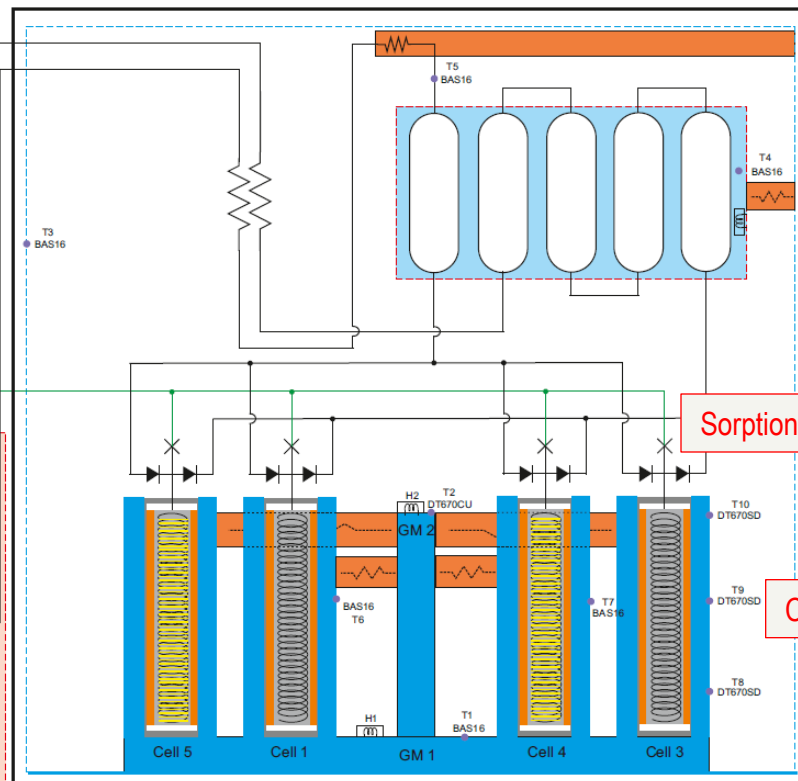
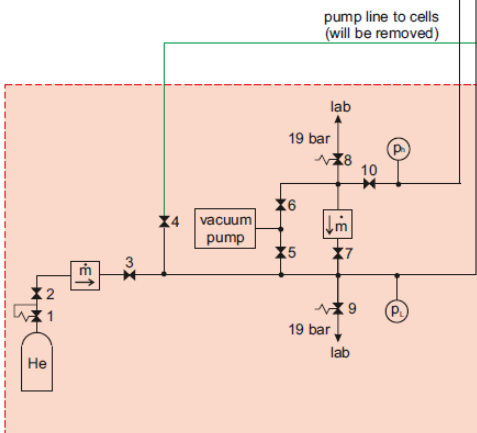
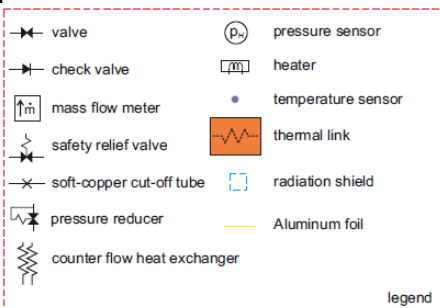
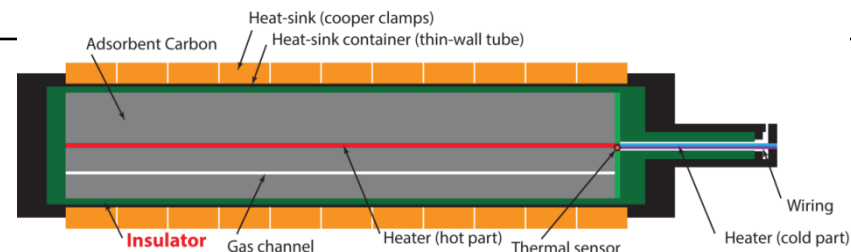
Switchless compressor design: 48 cells, input 535 W
101.4 mg/s; 0.5 W @ 8K (+25% in Q_c , + 10% in P_{in})

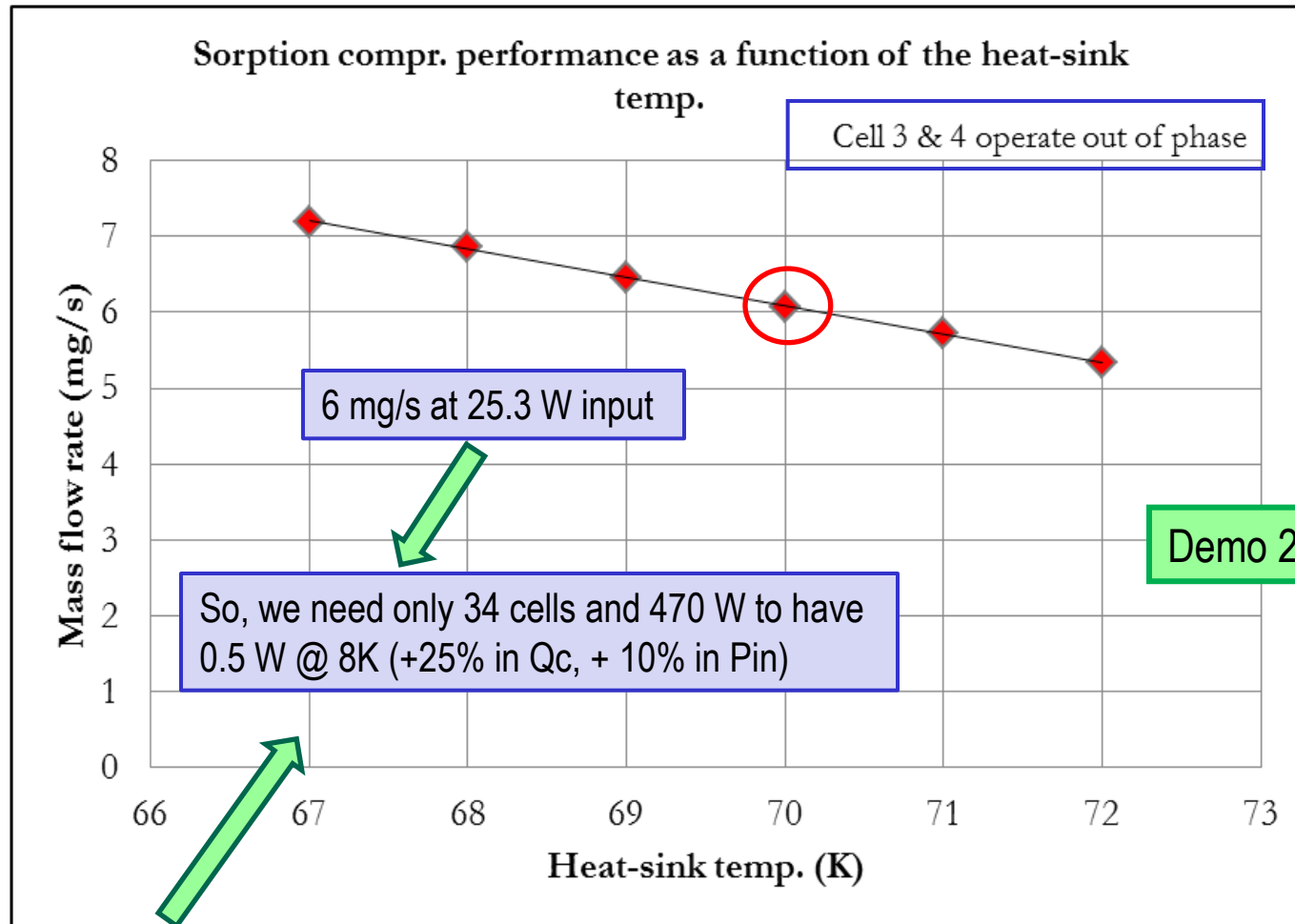
Compressor cell assembly:



Demo 2: scaled He sorption compressor

experimental setup





Demo 2: succesfull !

Switchless compressor design: 48 cells, input 535 W
101.4 mg/s; 0.5 W @ 8K (+25% in Q_c , + 10% in P_{in})



Corresponding to 2 cells, input 22,2 W: 4.7 mg/s

Demo 3: almost full-size Ne-based sorption cooler

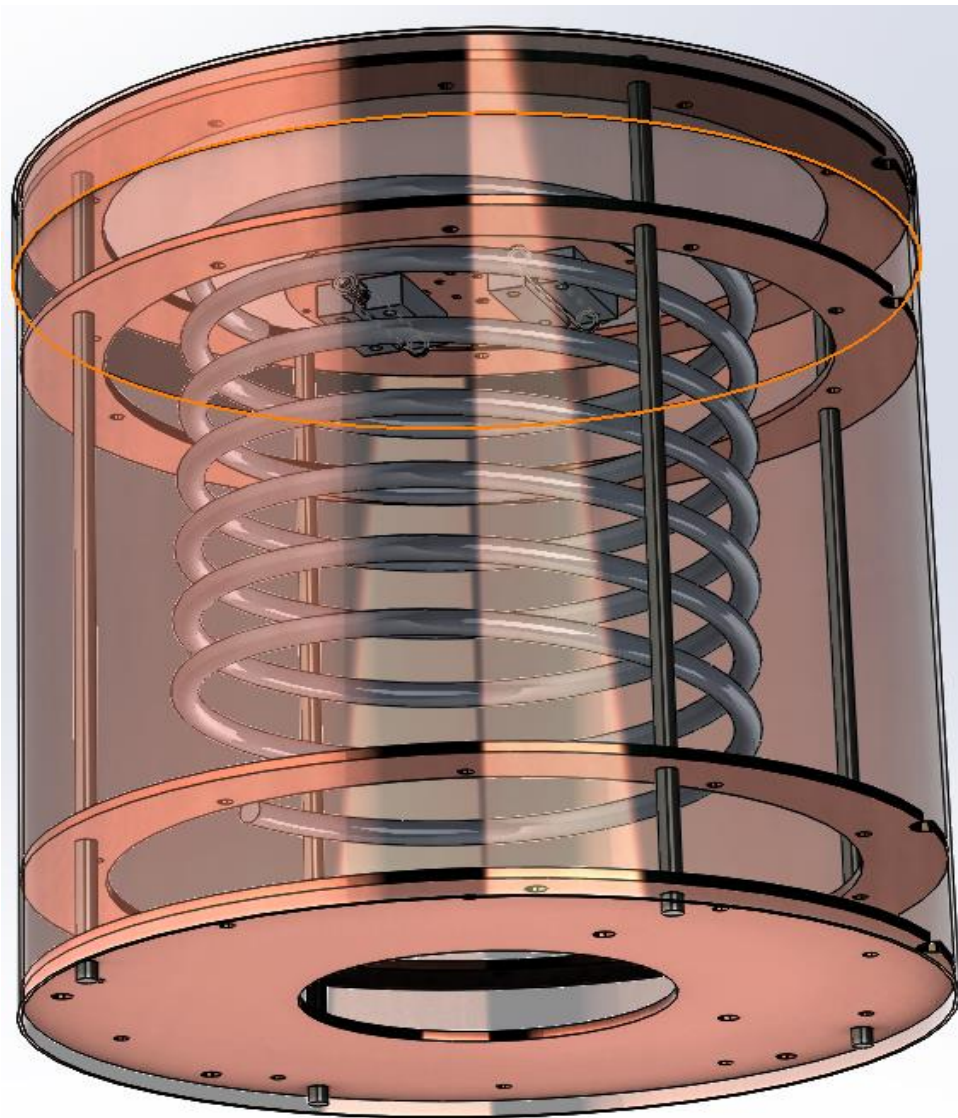
Specifications for compressor in demonstrator:

- Heat-sink temperature: 70 K
- High pressure: 112 bar
- Low pressure: 13.6 bar
- Mass flow: 48,7 mg/s
- Input power (4 cells): 67,3 W

Specifications for cold stage tests only:

- Starting temperature: 77 K (not 70 K)
- Tip temperature: 40K
- Cooling power: 1W nett;1.25W gross
- High pressure: 112 bar
- Low pressure: 13.6 bar
- Mass flow: 44 - 49 mg/s
- Two-phase temp.: 39.5K (at 13.6 bar)

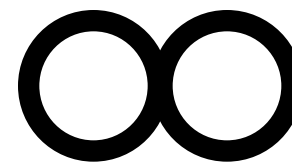
Demo 3: almost full-size Ne-based sorption cooler cold stage



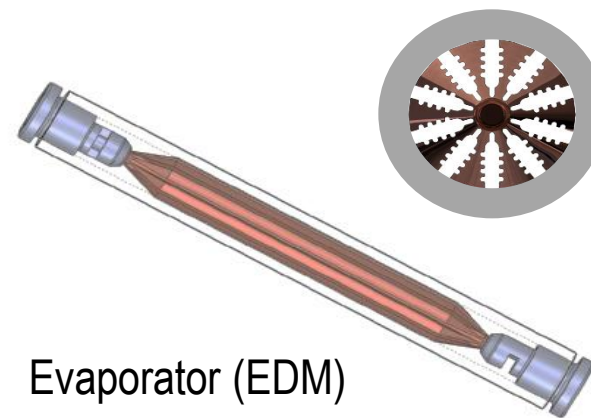
Cool down time (estimation):

From 70K : 6 hr

From 300K: 2 days

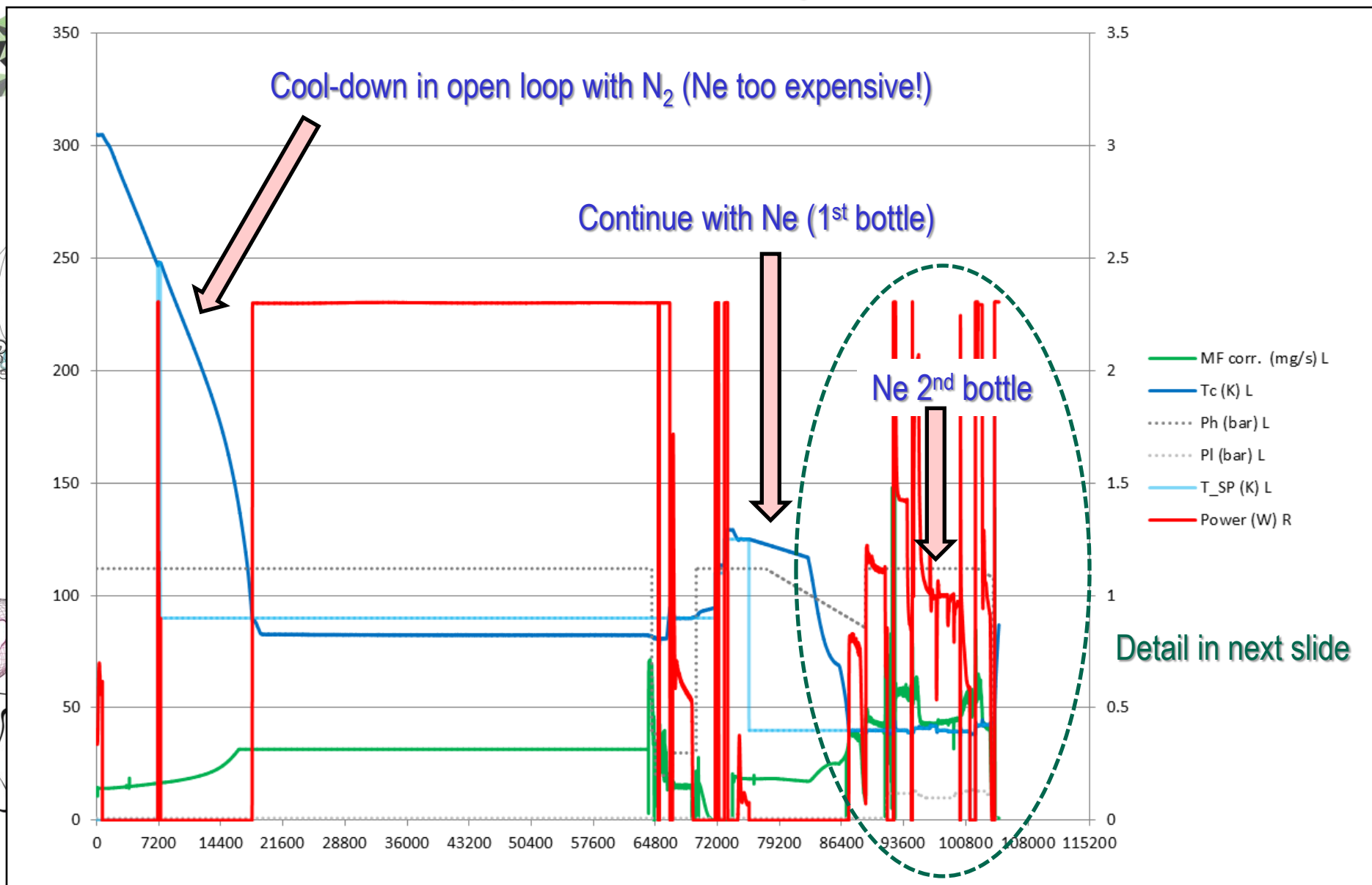


CFHX: SS: 1/8/3.2 mm, length 3m

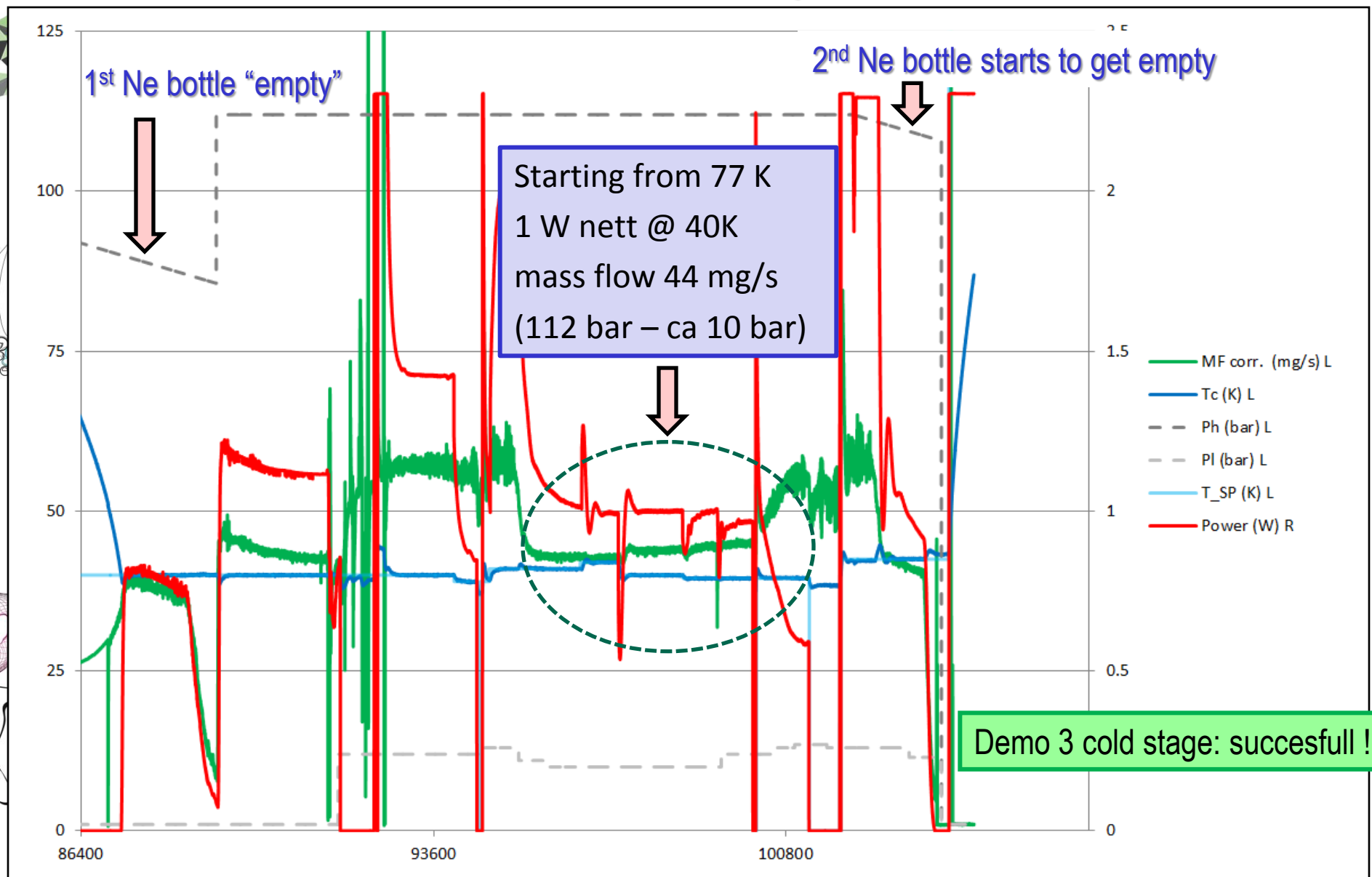


Evaporator (EDM)

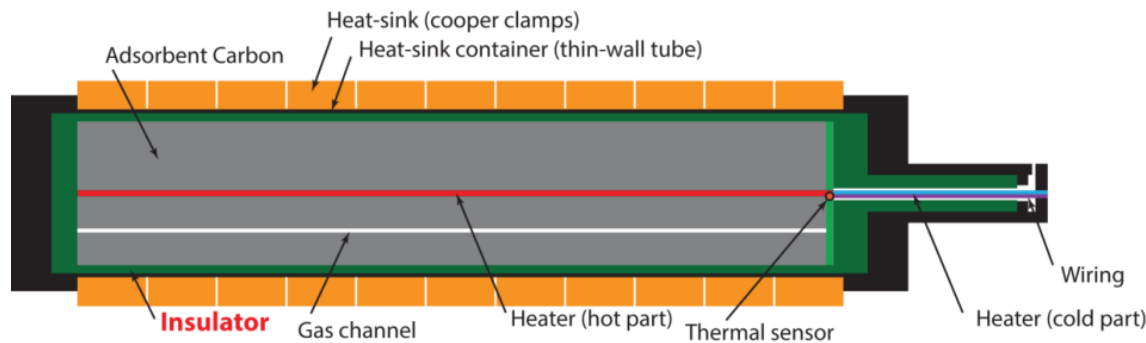
Demo 3: almost full-size Ne-based sorption cooler cold stage



Demo 3: almost full-size Ne-based sorption cooler cold stage



Demo 3: almost full-size Ne-based sorption cooler compressor



Design of neon-based compressor cells, as delivered to Airbus DS:

4 cells 500 mm long

Carbon pills, diameter 14,3 mm, thickness 5 mm

Heater diameter 1 mm

Insulation kapton 2 mm, Airbus DS uses teflon, 2,8 mm



Production of compressor plus integration and test is at Airbus DS

1. Baseline design completed ($Q_{\text{cool}} + 25\%$, $P_{\text{in}} + 10\%$) :
0.4W @ 8K; 1.1W @ 25K; 1.4W @ 40K .
Total: 80 cells length 50 cm diameter 2 cm ; 1kW input dumped in 70K LN2 bath,
2. Helium cold stage qualified 0.4W @ 8K, 100 mg/s
3. Scaled-down helium compressor qualified, extension to full scale: 35 cells instead of 48
4. Neon demonstrator 1W @ 40K under construction at Airbus DS, cold stage qualified

Acknowledgment

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